An Automated Data-Gathering Tool for Earth Observation CubeSat Classification

Alejandro I. Lopez-Telgie, Mario Quappe-Gutiérrez, and Walter Abrahão dos Santos

***Abstract*— This study presents an automated tool designed for the classification and analysis of Earth Observation CubeSats, with focus in the low Earth orbit (LEO) region (200-1,000 km altitude). Leveraging an integration of data from different reputable databases, the tool provides a detailed data repository which facilitates analysis of CubeSat deployment trends, configurations, and operational orbits, aiding in mission design. A key finding from our analysis is the pronounced concentration of CubeSats in certain LEO regions: Sun-Synchronus and ISS, with the United States as a leading contributor in CubeSat deployments. Moreover, the tool offers a comprehensive estimation of lifecycle costs associated with CubeSat missions, highlighting a trend of decreasing costs among major CubeSat developers such as Planet and Spire. This cost reduction trend is attributed to economies of scale, implementation of ground segment infrastructure, and vertical integration in the development of the satellites. By providing a detailed dataset, and classification of CubeSats, along with an analysis of cost trends, this research contributes valuable insights for the planning and cost optimization of future space missions. The findings underscore the growing commercial viability and strategic importance of CubeSats in the evolving landscape of Earth observation and new space.**

Link to graphical and video abstracts, and to code: https://latamt.ieeer9.org/index.php/transactions/article/view/8620

***Index Terms*—Cubesat, Nanosatellites, Small Satellites.**

I. Introduction

Since the proposal of the cubesat standard and its "container" by Bob Twiggs and Jordi Puig Suari in 1999 [1], a total of more than 2000 CubeSats have been deployed into orbit as of January 1st, 2024 [2]. Different databases [3], [4], [5], [6], [7], [8], [9] record their launches, several small satellites (below 600 kg) forecasts are regularly issued by non-profit and for-profit organizations [10], [11], [12], [13], and several articles have been written to analyze their evolution and capabilities [14], [15], [16], [17], [18], [19], [20].

The number of cubesats has significantly risen since 2011accounting for over 2000 satellites driven mainly by commercial players deploying their clusters, operating multiple spacecraft to fulfil a common goal, whereas just Planet and Spire's constellations account for 774 satellites as of Jan. 1, 2024[2][6]. While Planet and Spire operate using cubesats for remote sensing from Low Earth Orbit (LEO), they have different primary missions. Planet emphasizes high-frequency Earth imaging, while Spire concentrates on data collection for global tracking services in the maritime and aviation sectors. Cubesats play a relevant role in earth observation due to a combination of the standardized interface, reduced launch costs, shorter development times, and availability of commercial off-the-shelf (COTS) components. They can provide a 3 to 5 m Ground Sample Distance (GSD) with high revisit time (or temporal resolution), enabling new services. De Souza's [20] analysis indicates that small satellites are becoming increasingly competitive; they have become an alternative to bigger satellites for most types of optical missions.

This work presents an automated strategy for data-gathering which allows for the classification of Earth Observation cubesats and their major constellations, between 200 and 1.000 km altitude, through the consolidation of different reliable and up-to-date databases to classify their evolution and look for patterns that could help future design early phase conceptual mission design and analysis.

The following sections provide highlights on the verification process for the developed database and the classification of the last two decades of cubesats missions in different aspects, such as configuration, orbit, and country of registry. It further provides a relevant lifecycle cost estimate for the entire system by taking publicly available funding rounds and comparing them to deployed spacecraft over a range of periods to estimate a cost per satellite that encompasses the whole lifecycle and infrastructure of the system.

II. Cubesat Classification and Cost Estimation

A. Cubesat Classification Literature and Databases Review

Different authors have published cubesats classification analyses, with Bouwmeester & Guo [14] providing one of the first surveys in 2010, Swartwout [16] with an analysis of the first 100 cubesats in 2013, Polat & Romano [21] in 2016 with nearly 400 cubesats, Villela et al. [19] in 2019 with the first 1000 cubesats. Yet their databases remain a black box, and the static nature of an article fails to capture the dynamic essence of CubeSats. As stated by Poghosyan & Golkar [17] "the dramatic increase in the number of CubeSat missions over the last few years combined with their short development times indicate that surveys older than 3–4 years miss most of significant CubeSat developments." Hence the need for a tool that allows keeping up-to-date data for relevant trends analysis.

Different databases are summarised in Table . The number of Cubesat identified by the author's is twice the data from Celestrack (Note data obtained on May 5, 2021, corresponds

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to the period between Jan 1, 2002 and Dec 31 2020). The difference with respect to Nanosats [3] and Swartwout [8] is partially explained by including the deployed spacecraft until the time of this table compilation.

Satellite database, in Table I, characteristics are summarized below:

- Celestrack: Provides data from launched spacecraft with updated orbital elements. Classifies only a fraction as cubesats.
- NASA NSSDC[2]: Provide a single sub-website per spacecraft, but no consolidated list or table is available.
- M. Swartwout CubeSat Database: The list is not publicly available since the lead author partnered with Seradata; it only provides aggregated data.
- Nanosats.eu: Provides aggregated data.
- Gunter's space page: Provides significant mission data, but no up-to-date orbital data.
- UCS[3] Satellite Database: Provides an extensive list of satellites (not classified as cubesats directly) with data about user type[4] and purpose[5].
- Authors database: Cubesat detected in the same range of other aggregated sources, with updated orbital data combined with additional data as one Excel file.

TABLE I
RELEVANT SATELLITE DATABASES (AS OF OCTOBER 2023)

Database	Last update	Refresh rate	# of cubesats	Ref
Celestrack	Oct 2023	Frequent	385	[5]
NASA NSSDC	*N/A*	*N/A*	*N/A*	[22]
M. Swartwout CubeSat Database	*Dec 2019*	*N/A*	*2158*	[8]
Nanosats.eu	*Jan 2023*	*Frequent*	*2192*	[2]
Gunter's space page	*2023*	*Frequent*	*2722*	[6]
UCS Satellite Database	*Jan 2023*	*Half a year*	*N/A*	[9]
Authors database	*May 2021*	N/A	1071	

B. Cubesat Cost Modelling Literature Review

Regarding the cost estimation of Cubesats, Nag et al. [23] concluded that the application of current (as of 2014) parametric cost models, like the Small Satellite Cost Model or the analytical RAND model have a gap below 20 kg (i.e. in the domain of CubeSats). It also emphasizes the need of reliable learning curve factors below 20 kg for use in Distributed Satellite Missions (DSMs) (See Le Moigne et al. [24] for an extensive description on DSM taxonomy).

Greenberg [25] discusses the estimation of schedule estimation relationships (SERs) to predict the duration of major milestones, such as Systems Readiness Review to Critical Design Review in NASA's lifecycle model [26]. It uses schedule data from NASA missions, which is out of the scope of CubeSats, yet SERs can be a relevant input to estimate manpower costs. The Leansat team has obtained relevant data on the schedule between lifecycle phases in [27].

[2] National Space Science Data Center
[3] Union of Concerned Scientists
[4] Government; Military; Commercial; Others
[5] Space Science; Earth Observation; Technology Development; Communications; Navigation/Global Positioning

The NASA/JPL effort to fill the gap in CubeSat and Microsat (<150 kg) cost models is materialized through the CubeSat Or Microsat Probabilistic and Analogies Cost Tool (COMPACT), presented in a series of articles [28], [29] and presentations in the NASA Cost and Schedule Symposium [30]. The initial version COMPACT V1 was composed of a single cost model which utilized a non-parametric k-Nearest Neighbours (KNN) regression algorithm to estimate the full lifecycle cost of a CubeSat mission based on the CubeSat form factor, the launch mass, the developer type, and the number of identical spacecraft to be flown. It evolved into KNN [28] algorithm that used Euclidean distance as a measure of similarity to formalize the analogy method. COMPACT V2 builds upon the COMPACT V1 prototype, with a larger and updated dataset (from 24 in V1 to 35 (with 17 new missions launch after 2017). It changed the input parameters of the model, and use of Principal Components Analysis as a means of weighting the input space to remove correlations between input variables.

III. MATERIALS AND METHODS

The research presented here is divided into two main areas. The first relates to building a consolidated database that allows for up-to-date analysis of deployed cubesat missions, and the second to estimate the overall cost of a mission, focusing on the two companies that have deployed the most significant number of cubesats to date into orbit.

Multivariable analysis, through clusters, groups cubesat missions into distinct categories based on shared characteristics, such as orbit, bus configuration (number of units). Comparing costs within these clusters provides benchmarks for new missions within the same category.

A. Automated Data-gathering Tool Algorithm

An algorithm for data gathering was developed and implemented to allow for the integration of different datasets available online from reputable references such as Celestrack [5], NASA National Space Science Data Center (NSSDC) [22], UCS [9], and Gunter Kreebs Space Page [6]. It starts from the Satellite Catalogue (SatCat) and then queries the following databases to identify cubesats and catalogue them by the number of units. A high-level overview is presented in Fig. 1.

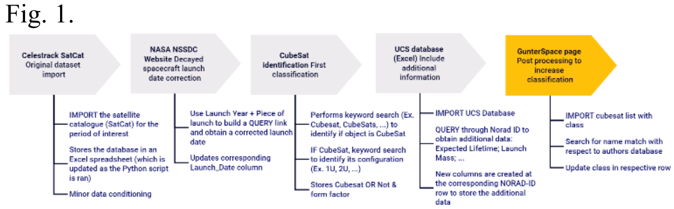

Fig. 1 Data extraction and high-level integration steps

The web scraping algorithm, Fig. 2, performs its queries in the different datasets, in a process that takes half a day running, followed by "manual" specific analysis of the integrated data as follows:

- Celestrack imports the entire SatCat and filters the data within the time interval of interest (this is the starting point for all future queries).

- NSSDC database is queried through a URL link built based on the Cospar ID. This is used to correct the launch date of decayed satellites (which the SatCat stores as launched in 1998; see Table III).
- UCS is downloaded (it provides an Excel database every six months), and the Norad ID is used to match the rows in both databases and import the additional data from UCS in the case of matches.
- Gunter Space Page is queried through satellite names and keywords to match remaining satellites as known cubesats and determine their form factors.
- Further data conditioning is done by the use of keywords to classify known constellations, such as Planet Dove, Flocks, or Spire Lemurs, as triple unit cubesats.

Data conditioning routines are implemented in the Python code and Microsoft Excel data repository to allow for further analysis. The algorithm is presented schematically in Fig. 2. The final results are stored in a Microsoft Excel repository, which is used for further analysis as presented in the results section.

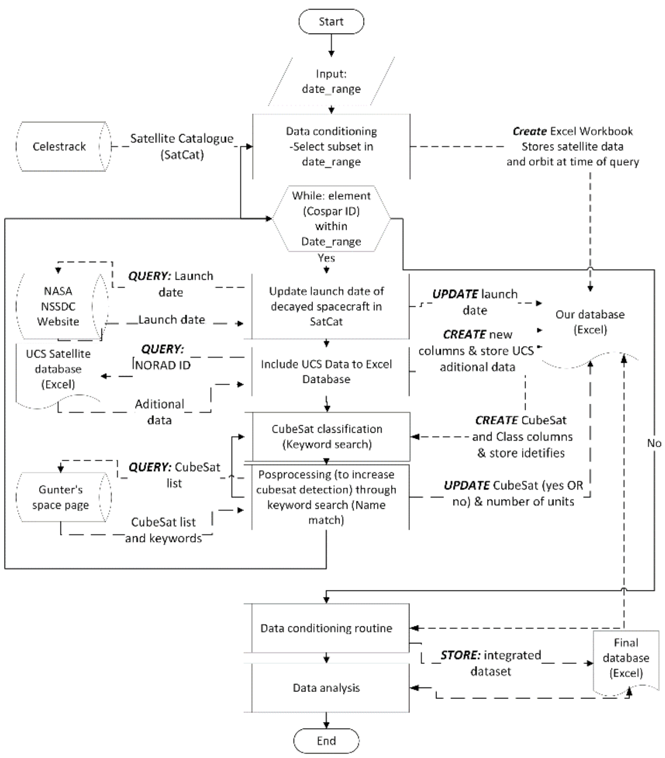

Fig. 2 Schematic representation of the algorithm developed to gather and classify the cubesat data within the period of interest.

The initial Celestrack catalogue provides cubesat class, as can be seen in Table II, yet this misses a significant portion of the cubesats flown as 1.071 were detected by the author's algorithm, which matches values in equivalent time frames of other authors over 1.000 cubesats [3], [17], [19]. Thus, the value of the approach, and the rationale for building the tool which creates an up-to-date dataset.

TABLE II
CUBESATS IDENTIFIED IN ORBIT BY CELESTRACK AS OF MAR 3, 2023. SOURCE: [5]

Developer	Number of Cubesats
Spire	113
Planet	132
Other Cubesats	153
Total	398

The web scraping process described in Fig. 2 can be extended to other databases using different keywords for the web scraping.

TABLE III
EXTRACT OF SATCAT SEARCH RESULTS FOR DECAYED SPORT 3U CUBESAT, NOTE LAUNCH DATE SET AS 1998 SOURCE: CELESTRACK QUERY FOR SPORT AS OF OCTOBER 2023 [31]

International Designator	NORAD Catalog Number	Name	Source	Launch Date	Decay Date
1998-067UW	55129	SPORT	BRAZ	1998-11-20	2023-10-10

After the cubesat database is consolidated in the Excel spreadsheets, it is used to produce different classification figures over time (see Results), and as input (coupled with investment data) for analyzing the cost evolution of cubesat clusters.

B. Estimation of Unit Life Cycle Cost for Cubesat Missions

Using the publicly available data from investment rounds [31], [32], combined with the deployed cubesats clusters from the main actors' Planet and Spire, an estimation of the life cycle cost for all the segments of the space mission is calculated considering that all the funds raised were used to cover for development and increase in the number of satellites deployed into orbit. This is schematically described in Fig. 3.

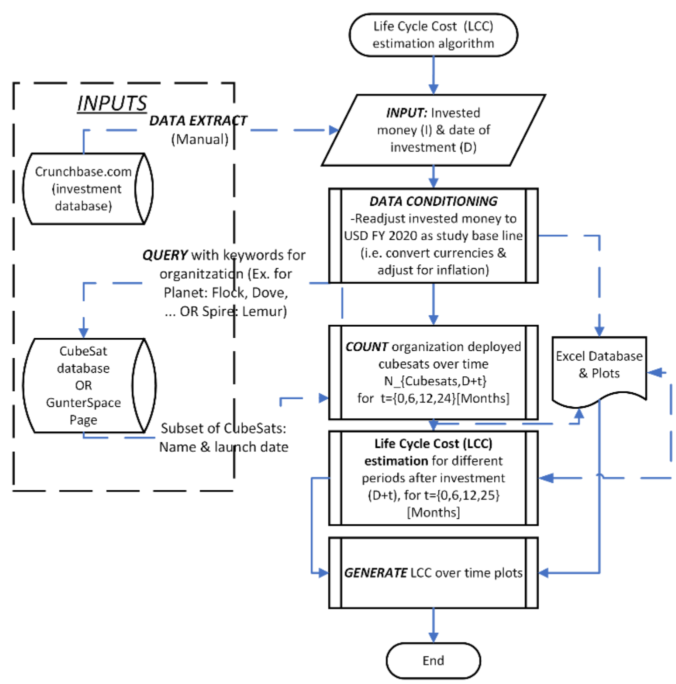

Fig. 3 Schematic representation of the algorithm developed to gather data and estimated the cubesat lifecycle cost.

Considering this, the number of satellites deployed in the periods of half a year, one year, or two years after each round of investment are taken into account to estimate the cost of each cubesat mission life cycle. This indirectly includes other costs, like ground segment, salaries, infrastructure, operation, etc. and how it varies over time as more cubesats are deployed, and companies gain insight into the process.

The estimation process takes the inflation-adjusted investment to date and divides it by the number of satellites deployed 6, 12 and 24 months after each round. This generates an estimate of the life cycle cost. Thus, the experiment looks to find differences in lifecycle cost derived from the mission payload.

$$C_{LCC,D+t} \approx \frac{\sum I_D}{\sum N_{Spacecraft,D+t}} [USD\ FY\ 2020] \quad \text{Eq. 1}$$

The estimated Life Cycle Cost C_{LCC}, in Eq. 1, is assessed for times $t = \{6,12,24\}[Months]$ after the investment at date D. Where, $\sum I_D$ is the sum of the invested money (adjusted by inflation) at time D, and $\sum N_{Spacecraft}$ is the sum of deployed spacecraft at time $D + t$.

IV. Results

A detailed breakdown of the data is provided in the following sub-sections. It starts by benchmarking obtained data for its verification and then it delves into the analysis. The verification of the database required efforts to produce subsets of data in comparable timeframes and figures from different aggregated publications, and novel analysis looking for cost-effective principles. This is detailed in this section.

A. Verification of the Obtained Dataset

To verify the data gathered, published results from Bryce Small Sats by the Numbers [11] were used for a selected subset matching the time interval of the publication, which can be seen in Fig. 4and Fig. 5.

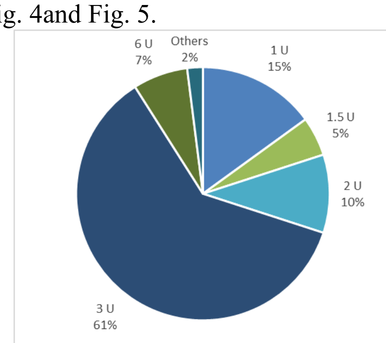

Fig. 4 Cubesat class breakdown for a subset of 574 from database analysis.

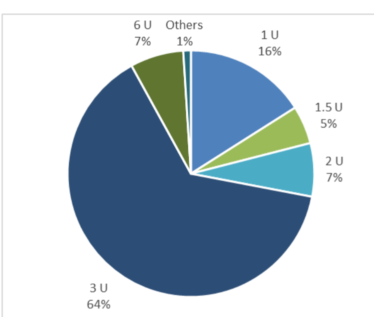

Fig. 5 Cubesat class breakdown as provided by Bryce [11].

Then the data was filtered to fit cubesats as a form factor rather than weight. In Fig. 4, the distribution by configuration as number of units matches to what was expected. Further review shows that the total number of cubesats detected by the algorithm between 2012 and 2018 corresponds to 82% with respect to the total provided by the Gunter Space Page [6] within the same period. The difference is attributed to the use of the Celestrack Satellite Catalogue as starting point, which considers only spacecraft that have reached orbit. Further analysis of the data and comparison with state of art is performed in the following sections.

B. Cubesat Database Main Characteristics

The data for missions over the last two decades was compiled from different available databases. Due to the sequence, using Celestrack orbital data as a starting point, it considers only spacecraft which have been launched and ignored announcements (which are considered by other databases). The detected cubesats launched by year are shown in Fig. 6.

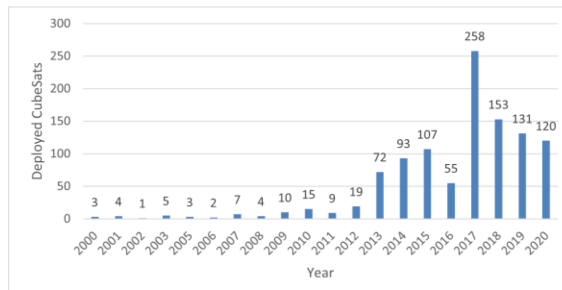

Fig. 6 Cubesats deployed per year between Jan 1, 2000 and Dec 31 2020. Note the second decade (2010-2020), accounts for 1032 versus 39 cubesats detected in the first (2000-2009) (Source: the authors).

The algorithm, through its python implementation, allows for data to be gathered and updated in half a day (not considering post-processing and analysis).

The data obtained on May 5, 2021, corresponding to the period between Jan 1 2000 and Dec 31 2020, identified 1.071 satellites as cubesats, which is over two times what is declared by Celestrack (see Table II). The data range was chosen to limit the influence of Covid pandemic over. It also provides configuration, and application data (civil, commercial, and others) which is analyzed in the following pages.

Classification by country of registry

For cubesat missions, the main countries of the registry are shown in Table IV, where the United States of America is the driver with a factor of 20 times with respect to the followers.

Table IV
Owner of Cubesat Missions by Country of Registry from Jan 1 2000 to Dec 31 2020 (Source: The Authors)

Country of registry		2000-2009	2010-2020	Total
United States	US	18	769	787
People Republic of China	PRC	1	33	34
Japan	JPN	-	29	29
Germany	GER	4	20	24
Commonwealth of Independent States (former USSR	CIS	1	16	17
Canada	CAN	3	7	10

United Kingdom	UK	-	10	10
Denmark	DEN	1	9	10
France	FR	-	10	10
Others with less than 10 Cubesats registered		11	129	140
Total		39	1032	1071

By unit form factor

The total breakdown is provided in Fig. 7, while the breakdown evolution over time is provided in Fig. 8. The main cubesat configuration detected is a triple unit (3U), with 51.6% over the last decades.

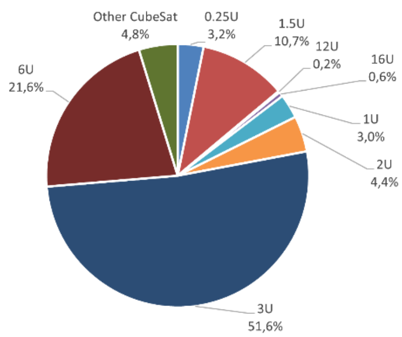

Fig. 7 Full database (2000-2020) cubesat configuration breakdown by the number of units.

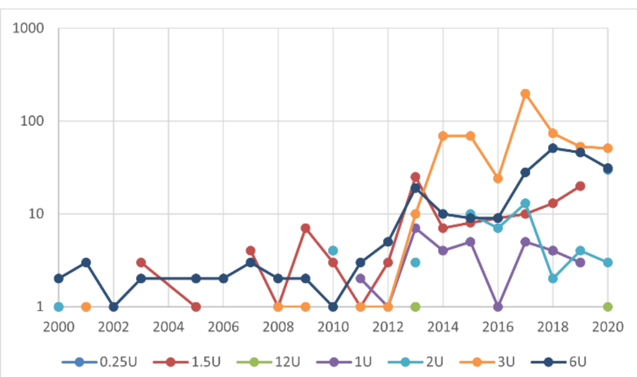

Fig. 8 Cubesats deployed by configuration between Jan 1, 2000 and Dec 31 2020.

The triple unit configuration is used by the two main users of cubesats, Planet and Spire, whose deployment is summarized in Table V.

TABLE V
RELEVANT SATELLITE DATABASES (AS OF OCTOBER 2023)

Year	Cubesats by Planet		Cubesats by Spire	
	That year	Total	That year	Total
2014	93	93	1	1
2015	50	143	4	5
2016	32	175	17	22
2017	140	315	46	68
2018	36	351	28	96
2019	32	383	16	112
2020	5	388	12	124
Total		388		124

By orbital region

One of the main findings of the analysis is that almost 80% of all the cubesats deployed over the last decade do so in two specific sub-regions of Low Earth Orbit (below 800 km altitude). These are defined as International Space Station (ISS) due to the match in inclination and the range of altitude related to the station operational range and Sun Synchronous Orbits (SSO) inclination and altitude. This is described in Table VI and Table VII.

TABLE VI
DETECTED CUBESATS BY ALTITUDE RANGES (SOURCE: THE AUTHORS BASED ON DATA FROM CELESTRACK SATELLITE CATALOG OF MAY 5TH 2021)

Orbit altitude [km	Number of cubesats	Percentage of total [%]
≤500	647	60.4
Between 500 and 800	389	36.3
≥800	27	2.5
Data not available	8	0.7
Total	1071	

TABLE VII
DETECTED CUBESATS BY INCLINATIONS AS OF MAY 5TH, 2021(SOURCE: THE AUTHORS)

Orbit inclination [°]	Number of cubesats	Percentage of total [%]
51.6±1 (i.e. ISS)	299	27.9
98±2 (i.e. SSO)	585	54.6
Others	179	16.7
Data not available	8	0.7
Total	1071	

The data is also grouped and plotted in Fig. 9, where the circle radius represents the number of satellites deployed in a specific combination of altitude and inclination.

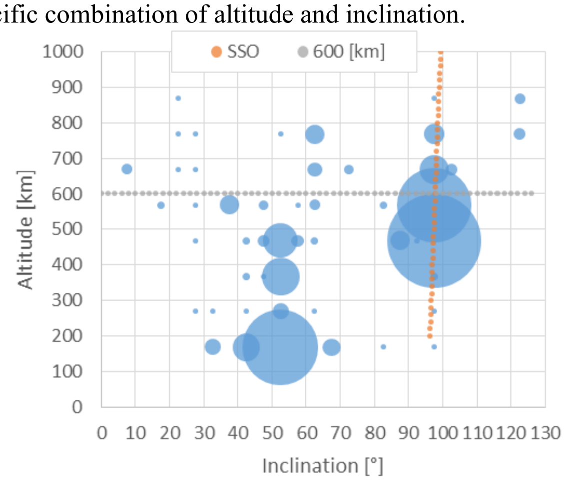

Fig. 9 Cubesat orbit by altitude and inclination.

The evolution over time of the last plot is shown in Fig. 10. According to Buzzi et al. [33], for orbital altitudes below 400 km, and depending on the solar cycle at launch time, the cubesat can reenter in less than one year. For the case of 500 km, it can take seven years, and above 750 km altitude, it will not comply with debris mitigation guidelines due to a reentry period above 25 years. Note satellites below 200 km correspond to satellites which have reentered the earth's atmosphere (which are detected as cubesats by the tool).

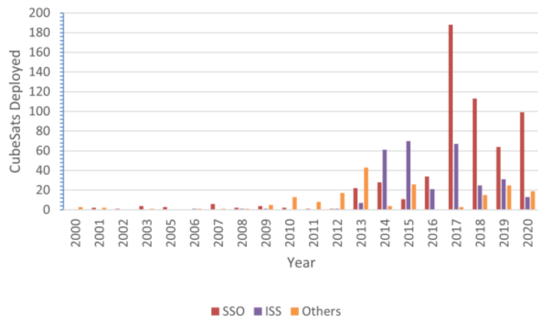

Fig. 10 Cubesats deployed per the region over time.

In summary, 96.7% of the detected cubesat are in LEO under 800 km altitude. In addition, 54.6% are in the defined SSO combination (see the orange line in Fig. 9), and 27,9% are in the ISS region. Orbital decay effects for ISS altitudes have been observed, with nearly 50 cubesats having decayed between the datasets of 2020 and 2021.

Launch to the subregions in Fig. 9, is attributed to the frequent launches to both regions, resulting in a regular offer at a cost-effective price in the order of 50 thousand US Dollars per cubesat unit to LEO [34].

C. Lifecycle Cost

The data obtained for investment rounds (adjusted by inflation) and the accumulated satellites deployed after 6, 12 and 24 months, together with the LCC estimates, are provided in Table VIII and Table IX. The evolution of lifecycle cost estimates for Spire and Planet are shown in Fig. 11, Fig. 12, and Fig. 13 summarizes each year's deployments.

TABLE VIII
PLANET INVESTMENT ROUNDS IN MUSD FY2020 AND LCC ESTIMATES (SOURCE: AUTHORS)

Date	Company	Transaction	# of investors	Raised per round [MUSD]	Total Investment [MUSD]	D+6		D+12		D+24	
						# of Sats	C_{LCC}	# of Sats	C_{LCC}	# of Sats	C_{LCC}
25-06-2013	Planet	Series A	7	14.54	14.54	28	0.52	39	0.37	109	0.13
18-12-2013	Planet	Series B	12	57.72	72.26	39	1.85	92	0.79	143	0.51
20-01-2015	Planet	Series C	17	128.40	200.66	117	1.72	143	1.40	175	1.15
14-04-2015	Planet	Series C	8	25.07	225.73	131	1.72	163	1.38	263	0.86
31-03-2018	Planet	Secondary Market	1	0.00	225.73	320	0.71	351	0.64	383	0.59
20-02-2019	Planet	Series D	0	169.68	395.41	414	0.96	383	1.03	414	0.96
Total			71		395.41						

TABLE IX
SPIRE INVESTMENT ROUNDS AND LCC ESTIMATES (SOURCE: AUTHORS)

Date	Company	Transaction	# of investors	Raised per round [MUSD]	Total Investment [MUSD]	D+6		D+12		D+24	
						# of Sats	C_{LCC}	# of Sats	C_{LCC}	# of Sats	C_{LCC}
14-07-2012	Spire	Product Crowdfunding	0	0,11	0,11	0		0		0	
07-02-2013	Spire	Seed Round	5	1,33	1,45	0		0		1	1.45
11-07-2013	Spire	Seed Round	1	0,33	1,78	0		0		1	1.78
19-07-2013	Spire	Seed Round	1	0,28	2,06	0		1	2.06	1	2.06
17-10-2013	Spire	Seed Round	1	0,83	2,89	0		1	2.89	5	0.58
29-07-2014	Spire	Series A	8	27,33	30,22	1	30.22	1	30.22	14	2.16
11-06-2015	Spire	Grant	1	2,84	33,06	5	6.61	11	3.01	34	0.97
30-06-2015	Spire	Series B	5	43,68	76,74	5	15.35	14	5.48	42	1.83
16-11-2017	Spire	C- Series	3	73,91	150,65	78	1.93	96	1.57	108	1.39
Total			71	150,65							

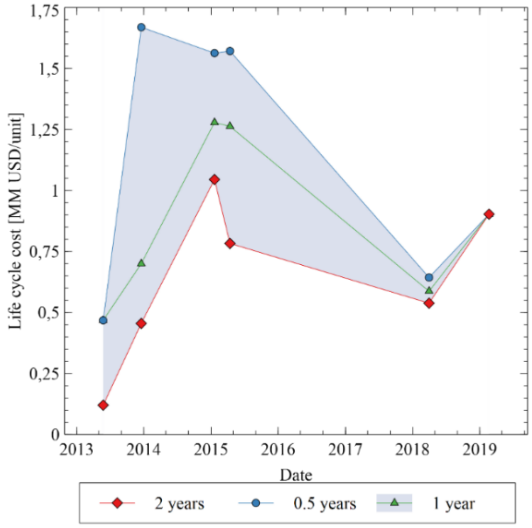

Fig. 11 Life cycle cost estimates for Planet 3U cubesats.

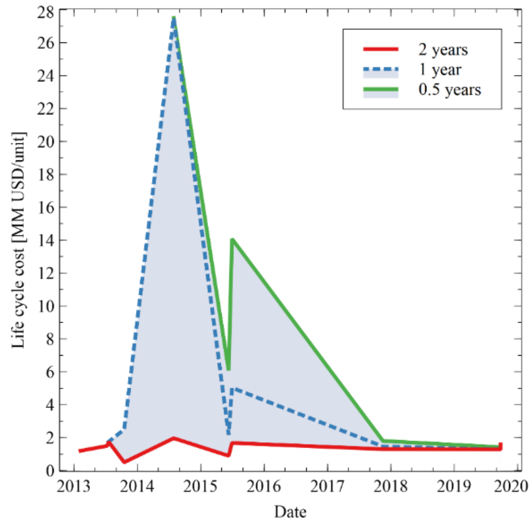

Fig. 12 Life cycle cost estimation for Spire cubesats.

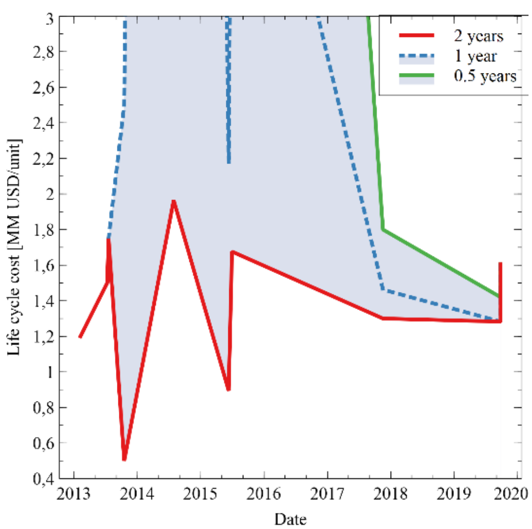

Fig. 13 Life cycle cost estimation for Spire cubesats zoom-in.

D. Life Cycle Cost Results Discussion

The estimation for Planet satellites considers 414 spacecraft deployed until Feb 20, 2019, and a total investment of 395 million US Dollars (FY 2020) [31]. Also includes the investments required for deploying 45 ground stations, personnel, and others, assuming all the investment was used to grow the constellation. It went down to 600.000 USD per 3 Unit Spacecraft in 2018.

For Spire clusters, it starts with high investment, which drives the money per spacecraft for the scenarios considering the launches in 6 and 12 months, to tens of millions of USD (which is out of expected value), and it goes down from it converges to 1.3 to 1.6 million USD for Spire constellation. In both graphs, there is a peak in 2018-2019.

It is relevant to note a decreasing cost per unit in time. It can be inferred that the ground segment investments to enable the systems have been significantly spent. Hence the cost of the following units can decrease. Therefore, a decrease in the life cycle cost of future units can be expected.

Also, the platforms from Planet and Spire have different missions, see Table X, the first with a telescope for passive visible and near-infrared bands earth observation. Spire receives AIS GNSS-RO and ADS-B signals (as of July 2018) for ship and airplane tracking [35]. The latter results in a spacecraft at around 4 kg.

TABLE X
PLANET AND SPIRE SATELLITE

Company	Planet	Spire
Service	Provide daily optical satellite data	Provide tracking (AIS, ADS-B) and weather services
Platform name	Dove	Lemur
Satellite frequency bands	X-Band system with patch antenna for Downlink S-Band for Uplink Backup UHF DL/UL	Transmit data in UHF, S and X-bands.
Licensed	Licensed bands under Non-GEO Satellite Orbit Federal Communications Committee (FCC) [1]	Licensed bands under Non-GEO Satellite Orbit Federal Communications Committee (FCC)[2]
Satellite bus	3 U bus with deployable solar array (wings)	3 U bus with deployable solar array (wings
Source	[36], [37], [38]	

Both companies follow a vertical integration approach by performing in-house assembly and integration of their platforms. They deployed extensive ground segments and reception capabilities to lower the overall response time, which resulted in significant investment in the early stages.

Challenges in maintaining an up to date database, considering the rate of change in cubesats as they transition from educational tool into service platforms. The analysis allows to constrain the solution search space for cost effective missions though analogy to the orbits and configurations being use an their evolution over time. In the later, we can se the emergence

[1] https://docs.fcc.gov/public/attachments/DA-23-799A1.pdf
[2] https://docs.fcc.gov/public/attachments/DOC-397617A1.pdf

of the six unit bus as the platforms mature and require more power (coupled with decreased in launch costs as new players have entered the industry over the two decades since the appearance of CubeSats).

V. CONCLUSION

A tool to gather cubesat data from different databases has been integrated and verified against relevant sources. This tool can detect cubesats, their orbits and platform configuration (in terms of the number of units).

Data for the decade between 2000 and 2020 has been analyzed. A total of 1.071 cubesats were detected, of which 54.6% are in a Sun Synchronous Orbit (SSO) and 27.9% in an International Space Station (ISS) like orbit. This represents a constraint to the search space for new cost-effective concepts.

Regarding the two main cubesat actors, Planet and Spire, a unitary life cycle cost for both have been estimated. They both present a clear decrease in cost per unit as the number of total units increases. Both curves converge to a price, which differs due to the different missions that both companies have. Both companies have obtained over 500 million USD in funding and have become relevant actors by using cost-effective design philosophies to deploy a service business model that employs cubesats in the space segment to gather relevant data at with high temporal resolution.

Regarding future research, further analysis is required to determine the numbeUr of active satellites over the deployed ones detected, their reliability over time, and the cost evolution as companies have covered the costs related to the deployment of their ground segments. Challenges remain in the access to data from cubesat developers, and keeping up with cubesat developments as platforms and commercial off the shelf subsystems due to their shorter development time.

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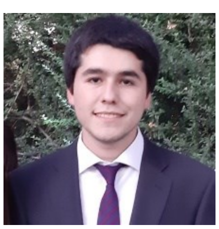

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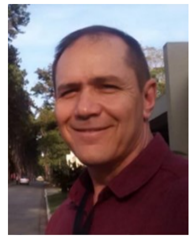

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